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Original Article

Artificial intelligence assisted Chest Radiograph assessment as screening tool for COVID-19

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Abbreviations:

COVID-19, Coronovirus Disease-2019
AI, Artificial Intelligence
ICU, Intensive Care Unit
CXR, Chest X-ray
RT-PCR, Reverse Transcriptase Polymerase Chain Reaction
CR, Chest Radiography
DR, Digital Radiography

ABSTRACT:

Aim and Objective: To study whether trained convolutional networks in artificial intelligence can be useful in assessing Chest radiographs of COVID -19 patients, to detect abnormalities and classify them as ‘Normal’, ‘Likely COVID-19’ and ‘Other abnormalities’ and detecting the Region of Interest (ROI) in Chest radiograph. **Materials and Methods:** The study was done on RTPCR positive Covid-19 patients. The study period being March to May 2020 in ICU and July 2020 to Feb 2021 ,in Department of Radiodiagnosis in Govt Medical College and ESI hospital, Coimbatore, India. 611 Chest radiographs taken during this period were initially reported by 2 senior radiologists. Then the same radiographs were processed into a prior trained and tested Artificial Intelligence software named CHOCO. The software detected and classified the radiographs into 3 sets –Normal, Likely COVID-19 and Other abnormalities respectively. The performance of AI software was compared with diagnostic performance of expert radiologists. **Statistical Analysis and Results:** Performance of the AI software was found to have 94.27% sensitivity, 93.79% specificity and 93.94% accuracy for detecting and classifying the abnormality. Detecting the Region of interest (ROI) in Chest radiograph was also done by the software with sensitivity of 92%, specificity of 86% and accuracy of 87.1%. **Conclusion:** The study shows that Artificial Intelligence software performs reasonably well with CXR image and can be used for rapid screening for a huge population.

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1. INTRODUCTION

The ongoing pandemic of coronavirus disease or COVID-19 caused by Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2), started in Wuhan China, where it was identified in a cluster of pneumonia cases, in December 2019. By end of January WHO declared the disease as a health emergency of international concern. WHO declared the disease a global pandemic on 11th March 2020. Globally over 164.2 million people were affected and the reported deaths were 3.40 million, according to WHO as on 15 May 2021. In India, the total COVID -19 numbers were 25 million and total deaths were 0.27 million as on 15 May 2021 [1]. Prior to this century, members of the corona virus family had minimal impact on human health. However, in the past 20 years, outbreaks have highlighted the emerging importance of corona viruses in morbidity and mortality. SARS in 2002 to 2003 and the MERS-Middle East Respiratory Syndrome in 2012, though less prevalent than COVID-19, had higher mortality rates. Hence it would be reasonably appropriate to assume that world will continue to see novel diseases with similar significant health and economic implications. The challenges presented to the health system by such novel pathogens are in developing methods to diagnose, prevent and treat the disease spectrum. There is a compelling need for an effective screening tool when overwhelming numbers of the population get affected. Reverse Transcriptase PCR (RT PCR) is the gold standard for diagnosing the COVID-19 [2]. The sensitivity of RT PCR is only 60-70%. Even after making test kits readily available, provision of these in large scale remains a challenge. Time for diagnosis in RT –PCR is 3 to 8 hours and its cost ranges between 700 to 5000 INR in India. Though RT-PCR is a trustable test, an effective screening tool is needed for rapid diagnosis and for triage, so that patients can be appropriately referred and treatment swiftly initiated [3]. There is a need for a tool which can help diagnose COVID 19, that can be used even in remote and rural locations and which can be easily applied to mass screening investigations like Chest radiographs. In our study we have made an attempt to use the cost-efficient Artificial intelligence software designed by CHS to diagnose COVID-19 in Chest radiographs (CXR).

Chest radiographs in COVID-19 are performed in asymptomatic and mildly symptomatic patients with COVID positive status. They are also typically performed in COVID patients in Intensive care units to assess frequently disease progression or improvement, and to diagnose Air leaks, Effusion and Cardiac involvement. CXR is the most cost efficient and safe mode of screening which is highly critical in a densely populated and economically diverse country like India. A chest X-Ray ranges from INR 100-250 (approximately) whereas a RT-PCR costs around INR 700 – 5,000. India has sufficient infrastructure which makes a CXR affordable to anyone especially to economically backward and rural regions. The quick testing and easy usage of the X-Ray aids the feasibility of mass pre-screening. This study is to analyse whether Artificial Intelligence (AI) based software is useful as a screening tool for diagnosing COVID-19 in Chest Radiographs (CXR). The performance of the tool is statistically analysed in this study with the help of the senior radiologists from Govt medical college and ESI hospital, Coimbatore –an exclusive COVID-19 designated hospital and CHS. Artificial Intelligence has been increasingly used in medical field in cardiology, ophthalmology, pathology, dermatology, radiology etc. [4,5]. In this study we have used Artificial Intelligence tool with CXR, to obtain effective, low cost solution and arrive at the results in a matter of minutes.

CHOCO is a specialised software which analyses chest radiograph and identifies the lung infections using AI. The product uses a deep neural network which is trained and tested with medical dataset. Cases of each class from pneumonia, pneumothorax, COVID-19, tuberculosis and normal CXRs were trained and the model was built [6-8]. The usage of this product is very handy and robust. Radiologists / technicians just need to upload a CXR image and within a reasonable time (2 sec on a recommended system configuration) the software predicts the possible infection in a lung. As soon as the image hits the model, the software extracts the features from the dataset and compares with earlier trained data. Based on the closeness of the feature map the software provides a confidence score for each infection, i.e. it classifies whether an image is “Likely COVID-19”, “Normal” or “Other abnormalities”. A suitable threshold is chosen based on various consecutive experiments and with a clinical trial of more than 1,000 cases with various medical institutions in order to retain effective/specific regions with abnormalities.

Since COVID-19 is an ongoing pandemic across the globe quick implementation of Research and Development tool like CHS CHOCO tool will have a good impact, especially in developing and largely populated countries like India [9-11]. The software if incorporated into the X ray workstation will help in early diagnosis and triage of patients even in rural settings where the radiologists are not available. An attempt has been made in this study on how existing technology can aid radiologist and health care workers for an effective screening of COVID-19.

2. MATERIALS AND METHODS

2.1. Study design

This is a retrospective and prospective observational study conducted in all patients with COVID-19 symptoms who were screened with chest radiograph for COVID-19 from March, 2020 to May,2020 from ICU Department & July, 2020 to February, 2021 from Radiology department, Government Medical College and ESI hospital, Coimbatore. The study was approved by Institutional Ethical committee, Government Medical College and ESI hospital, Coimbatore - Protocol No.: IHEC No. 20910 & 20920. Abnormal patterns in a Chest X-Ray image were studied to predict Likely COVID-19, Normal and other abnormalities in a lung. All RTPCR positive COVID patients who undergo CXR screening during this period of study were included. No selection of bias in terms of patients Age and Sex. Patients who cannot undergo chest X-ray and pregnant women were excluded.

2.2. Instrument

Chest Radiographs performed from March, 2020 to May,2020 from ICU Department & July, 2020 to February, 2021 from Radiology department and ICU, Government Medical College and ESI hospital, Coimbatore were reviewed. During this study two types of X-Ray equipment were used, Computed Radiography (CR) –CARESTREAM & Digital Radiography (DR) - CARESTREAM. We have conducted two studies as follows (1) Statistical study of the software CHOCO (AI/ML driven) which acts as an aid for the radiologist to diagnosing Covid-19, Likely Covid-19 and other abnormalities against normal, (2) Statistical study of the software CHOCO (AI/ML driven) in detection of Region of Interest (ROI) in Chest Radiographs (CXR) which acts as an aid for the radiologist to diagnosing COVID-19, Likely Covid-19 and other abnormalities against Normal.

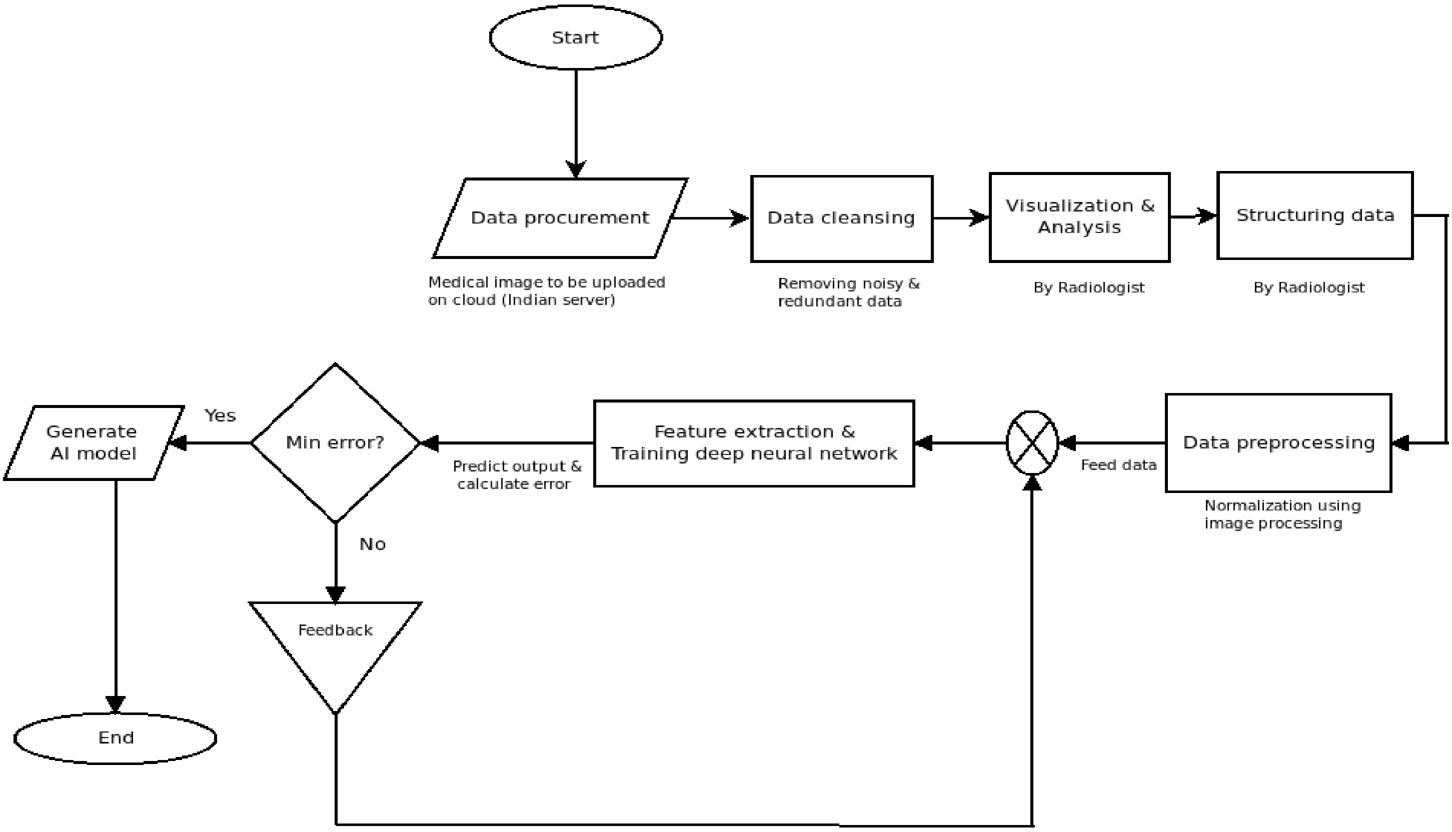
Start
Data procurement
Medical image to be uploaded on cloud (Indian server)
Data cleansing
Removing noisy & redundant data
Visualization & Analysis
By Radiologist
Structuring data
By Radiologist
Data preprocessing
Normalization using image processing
Feed data
Feature extraction & Training deep neural network
Predict output & calculate error
Min error?
Yes
No
Generate AI model
Feedback
End

Figure 1 Machine Learning Training Process Flow. Data procurement: The raw Chest X-Ray images (Monochrome-2) containing various lung infections such as COVID-19, pneumonia bacteria, pneumonia virus, normal cases, etc were uploaded to an Indian cloud server in the form of DICOM/PNG/JPG/JPEG.60,000 normal CXR and 59,000 Abnormal CXR including Covid-19 were used to train the software. Data cleansing: Noisy and redundant data were removed from the raw dataset. Visualization and analysis: Radiologists analysed the infection in available data. Structuring data: Based on the analysis of the data, radiologists classify the data based on the infection visible in the image and organise it in a structured manner suitable for AI training. Data pre-processing: The structured data is pre-processed by various image processing techniques. Feature extraction and AI training: Various features are extracted using feature extraction algorithms from the images fed into the network. Based on the extracted feature Deep Neural Network was trained to classify the COVID-19 lung infection. Error and feedback network: The network predict the output based on the learning and error is calculated at the end of each prediction. In order to minimise the error, a feedback circuit was implemented which fine tunes the learning parameter until the error reaches global minima. Generate AI model: The network created a model containing the valuable features for which the error is minimum. The features stored in this model could be used to predict the test data.

2.3. Statistical analysis

Data has been analysed using CHOCO software. Continuous variables are expressed and categorical variables are expressed using sensitivity and specificity. Accuracy value will be considered as statistically significant. The process of machine learning training and testing is shown in ***Figure 1*** and ***Figure 2*** respectively.

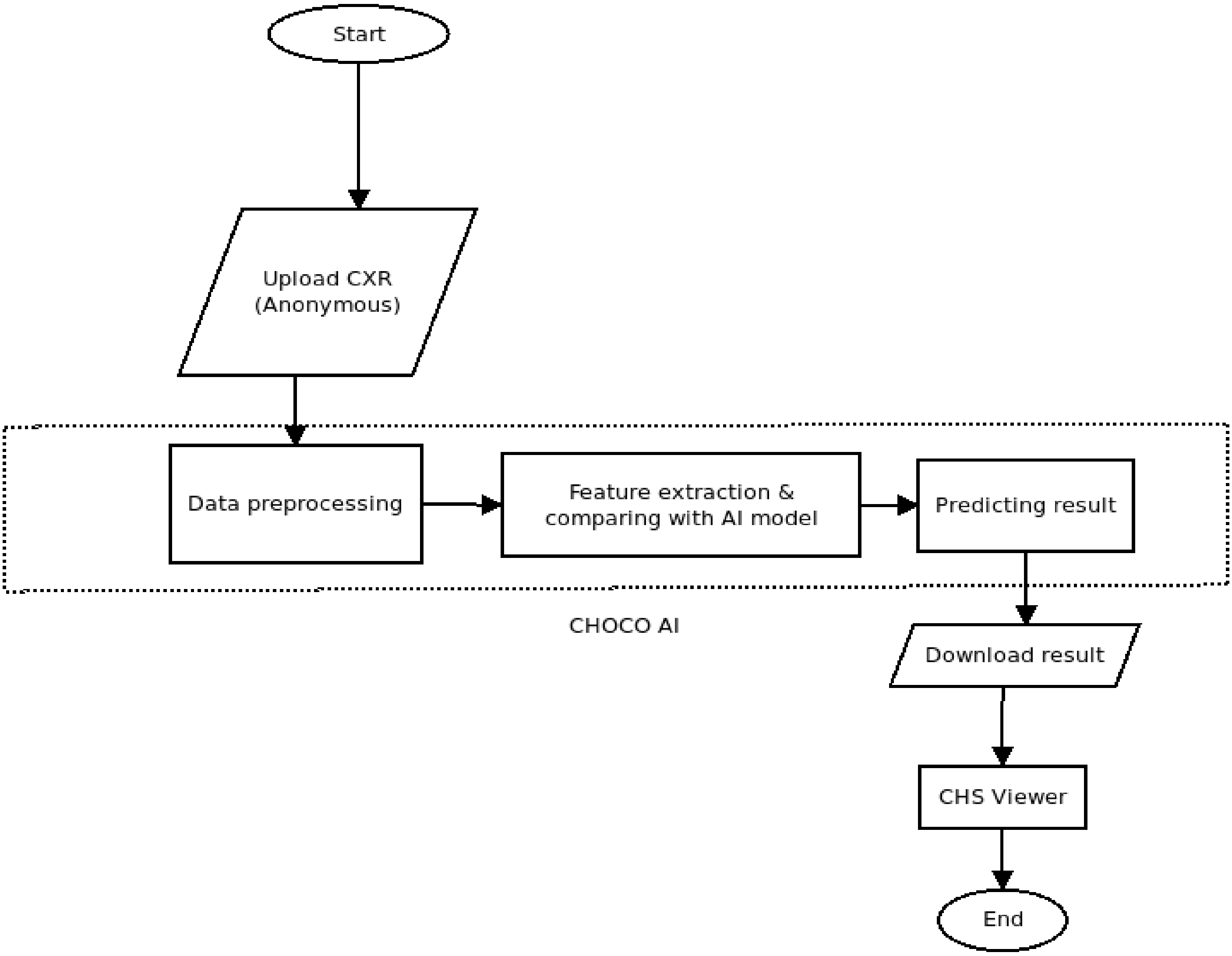

Figure 2 Machine Learning Testing Process flow. Patient walk in: Patients turn up for hospital. Register: In case of out-patients a registration is made where patient details and symptoms are noted. Capture CXR: A Chest X-ray is captured using CR/DR X-Ray machine. Upload CXR: The technician uploads the CXR image in DICOM/PNG/JPG/JPEG format by anonymising patient's information, along with the symptoms noted to CHOCO software (Indian cloud server). The image should be of type monochrome-2. Data pre-processing: The uploaded data is pre-processed by various image processing techniques. Feature extraction: Various features are extracted using feature extraction algorithms from the images fed into the network. The features are compared against the trained AI model. Predicting result: Based on the closeness of the features, the image is classified either as Likely COVID-19, other abnormalities or Normal case. Download result: The predicted label is marked on the output image and the file is downloaded to the user's local machine in the same format as it was uploaded. CHS viewer: The downloaded image can be viewed in CHS viewer.

3. RESULT

Statistical study of the software CHOCO (AI/ML driven) which acts as an aid for the radiologist to diagnosing Likely COVID-19 and Other Abnormalities against Normal. The product was deployed in Government Medical College & ESI Hospital, Coimbatore. Study was conducted for the month(s) (March, 2020 to May, 2020 from ICU

Department & July, 2020 to February, 2021 from X-Ray department) and all the COVID-19 infected patients were tested using CHOCO. The results are then validated by a team of radiologists as shown in Table 1.

Total Processed	**True Positive**	**True Negative**	**False Positive**	**False Negative**
791	344	400	19	28

Table 1 Statistical analysis showing CHOCO as an aid for radiologist

The result of the study was cross verified by the Radiologist from CHS. The result of the AI performance is sensitivity = 92 %; specificity = 92%; accuracy = 94.05 %.

Statistical study of the software CHOCO (AI/ML driven) in detection of Region of Interest (RoI) in Chest X-Ray which acts as an aid for the radiologist to diagnosing Likely COVID-19 and Other Abnormalities against Normal. The product was deployed in Government Medical College & ESI Hospital, Coimbatore. Study was conducted for the month(s) (March, 2020 to May,2020 from ICU Department & July, 2020 to February, 2021 from X-Ray department) and all the COVID-19 infected patients were tested using CHOCO. The results are then validated by a team of radiologists as shown in Table 2.

Total Instances	**True Positive**	**True Negative**	**False Positive**	**False Negative**
1121	577	400	53	91

Table 2 Statistical analysis showing CHOCO in detection of Region of Interest

The result of the study was cross verified by considering the Radiologist from CHS and they were considered as ground truth. The result of the AI performance is sensitivity = 92 %; specificity = 86 %; accuracy = 87.15 %.

4. DISCUSSION

It can be observed that apart from Likely COVID-19 and Normal classes, the product has predicted a third class namely, other abnormalities. The other abnormalities include Tuberculosis, Pneumonia (viral and bacterial infections) and Pneumothorax. It is not advisable to neglect these infections as these are of serious concern. Hence patients tested with other abnormalities can be taken to the next phase of testing. Common COVID 19 pattern identified in CXR was bilateral peripherally placed, lower zone haziness / consolidation, as was noticed in other previous studies [12-14]. It can be observed the AI-CHOCO not only classified/predicted the Normal & Abnormal, it helps as an aiding tool for the radiologists to identify the 'Region of Interest' over the abnormalities. Thus, it can increase the efficiency and performance of the radiologists. CXR also proved to be a promising screening method for most of the common lung infections till date. Applications of AI in classification of various types of lung diseases are numerous. Researchers across the world have experimented with classification of various lung diseases from a CXR using deep learning. Qin ZZ et al. [15] built an AI model to detect tuberculosis from chest radiographs. Puxuan et al. [16] observed that CXR provides a sensitive and specific method for the diagnosis and treatment of SARS in their publication during the 2003 pandemic of SARS. Xuanyang et al. [12] built a computer aided SARS detection system by extracting the features on the segmental pulmonary fields. They were successfully able to distinguish between pneumonia and SARS. Pranav et al. [13] has developed a deep learning-based model for the detection of pneumonia. Pneumonia being the most common lung infection, the disease must be taken into account while screening.

AI has multiple possible roles to augment conventional radiologic interpretation in COVID-19. AI helps in screening, triaging and rendering rapid diagnosis in COVID-19. AI can provide a rapid second opinion to help the radiologist confirm the diagnosis. In centres where radiologists are not available, AI can render definitive diagnosis. It helps in assessing disease severity and also to monitor the course of disease [14]. Also, it helps to diagnose other infections that are detectable from a CXR- which can be alternate diagnosis or superadded infections. AI helps in mass screening of suspect patients when PCR test results are delayed or when PCR is negative because of newer variants as part of viral mutation. Can be used for mass screening in places of mass gathering such as airports, railway stations, etc. where people tend to migrate into or within a country. Also, a mandatory screening is advisable in interior parts of the country such as a rural area. Luckily countries such as India are well established in effective use of available X-Ray technology. It is proven that this automated tool is developed using machine learning technology for quick screening from CXR. An average CXR costs just around Rs.100 to Rs.250 which becomes affordable to a large crowd. A testing with CXR might take about 10-15 minutes including the scanning which makes it feasible for mass scanning with limited human interaction. This tool may be much more effective than thermal detections in public places as the latter may give low level helpful information.

Thus, a simple diagnostic test such as CXR in combination with AI becomes a powerful tool to diagnose and prevent spread of COVID -19 contagion.

5. CONCLUSION

In conclusion, the study shows that CHOCO, a commercially available AI platform performs reasonably well with CXR image and can be used for rapid screening for a huge population. Apart from screening and triage, this software can be used to diagnose and monitor COVID-19 patients. Moreover, further prospective studies in variable demographics is needed for clinical implementation.

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Authors Contribution Statement

Subhashree C: Conceptualization, Methodology, Validation, Investigation, Resources, Writing – Original Draft.

Hariharan P: Software and Formal Analysis.

Kannadhasan R: Investigation, Writing – Review & Editing

Vimal Raj: Software

Sanjana Gowda: Software

Declaration of Competing Interest

None

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Supplementary material

File 1.

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